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The Effect of the Practice Specificity Principle on the Performance and Retention of a Perceptual-Motor Skill: A Quasi-Experimental Study with Application for Sports and Rehabilitation

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Original Article

Abstract

Introduction: This study was conducted to determine the effect of the specificity of practice principle on the performance and retention of dart-throwing skills.

Materials and Methods: This study employed a quasi-experimental design with an applied purpose. A pretest-posttest protocol was implemented across two training conditions (normal and specific), consisting of an acquisition period and a retention test for each group. The independent variable was the principle of practice specificity, while the dependent variables were the performance and retention of the perceptual-motor skill of dart throwing. The statistical population comprised students aged 12 to 15 years from 8th district of Tehran City, Iran. The final sample consisted of 30 participants who were selected through convenience sampling and randomly assigned into two groups of 15. Data were analyzed using descriptive statistics as well as independent t-test and paired t-test.

Results: The results indicated a significant difference in the performance on the post-test and retention of dart-throwing skills between identical and non-identical conditions in both the normal and specific training groups ($P < 0.001$). Specifically, performance on the post-test and retention phases that matched the training conditions was significantly superior to performance in mismatched conditions. These findings provide empirical support for the principle of specificity of training.

Conclusion: These findings are consistent with the specificity of practice principle, highlighting the significant impact of contextual conditions on subsequent performance. Based on these results, it is recommended that when teaching perceptual-motor skills, the environmental conditions of practice should closely mirror the real-world settings in which the skill is intended to be performed.

Keywords: Specificity principle; Performance; Retention; Dart throwing

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Introduction

The Specificity of Practice Hypothesis (Practice Specificity Principle), sometimes referred to in the literature as the Practice Specificity Principle, has been examined for nearly a century in research on the learning and re-learning of motor tasks and skills. The pioneering studies of Franklin Henry and his colleagues established a fundamental interest in motor

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tasks and the concept of practice specificity (1). According to this principle, the learning of motor skills depends on the sensory resources and contextual conditions available during practice. These sensory resources and practice conditions are specific to the Performance of a given skill and lead to optimal Performance. For example, visual afferent information serves as a particularly important sensory source during the learning stages (2). Thus, the extent of learning depends on the similarity between the features in the practice and retention phases. The addition or removal of sensory or contextual resources during the performance or testing phase of a criterion task reduces Performance (3).

The principle of Specificity of practice has demonstrated high levels of motor specificity effects across numerous experiments and has been examined in various domains (4). However, to date, no definitive conclusions have been reached, and research findings in this area have shown considerable variability. The results of most studies indicate that the expected level of Performance during actual competition decreases when individuals are exposed to certain variables. Accordingly, an important question is whether engaging participants in conditions aligned with the principle of Specificity of practice can help preserve the skills they have acquired. Based on analyses by scholars in motor learning and motor control, the principle of Specificity of practice through the concepts of sensory and motor Specificity, context specificity, and transfer-appropriate processing suggests that coaches and movement educators should align practice conditions as closely as possible with test conditions or criterion performance. This alignment enables learners to utilize environmental information more effectively and to engage in more appropriate and beneficial processing that facilitates skill improvement. Through this approach, learners can develop their learning in accordance with testing conditions or real performance demands. Another important consideration for instructors (coaches or therapists) during practice is to expose learners to situations that closely resemble those expected during criterion performance, whether in retention and transfer tests or in real-world performance (1).

In reviewing the research conducted in this area, Proteau and colleagues, by investigating the role of the visual component in motor learning, initiated extensive laboratory-based studies aimed at supporting the Specificity of practice hypothesis through the sensory variable of vision (5). Furthermore, the principle of Specificity of practice has been supported in tasks involving aiming movements (6), gait accuracy (7), weightlifting (8), golf putting, and rock climbing (9). In addition, this principle has been examined in other studies from various biomechanical, physiological, and information-processing perspectives. These investigations have employed biomechanical components such as movement patterns, joint angles, and velocity; physiological components such as types of muscular contractions and the energy systems involved; and processing components including practice models and practice conditions (1). Researchers have also examined psychological contextual components such as motivational characteristics and psychological states in relation to the Specificity of practice principle. For example, Movahedi and colleagues supported this principle in a real sporting environment by manipulating motivational conditions during the testing phase. In their study, two groups of participants learned a perceptual–motor basketball-throwing task under two motivational conditions (high and low motivation). After the acquisition phase, they were tested under motivational conditions that differed from those during practice. The results of this study demonstrated a decline in Performance when motivational conditions were altered from those present during practice, providing valuable evidence in support of the Specificity of practice hypothesis (3). These findings have been replicated in other studies examining the Specificity of motor skill learning to visual practice conditions (4) and have also been supported by investigations of the effects of sensory manipulations on motor behavior, as well as by providing guidelines for designing rehabilitation interventions and improving patient performance (10). However, although the aforementioned studies have presented strong evidence in support of the principle of Specificity of practice, other research has reported findings that contradict its predictions. In particular, field studies have documented inconsistent results regarding the Specificity of practice hypothesis. For example, one study examined the role of practice in the development of gross motor skills. In this study, participants practiced catching a ball under full-light conditions and in a dark room with an illuminated ball. The results showed that despite the different practice conditions, participants demonstrated equal accuracy during the post-test and transfer conditions. These findings do not support the practice specificity hypothesis (11). In another experiment, squat Performance in novice and expert powerlifters was examined under three visual conditions: full vision, reduced vision, and no vision. The results indicated that 90% of expert lifters who had trained under full-vision conditions maintained high levels of accuracy across all performance conditions (12). Similarly, within the field of rehabilitation, a study investigating the effects of perceived cutaneous pain on Performance and motor strategies during the practice and testing phases of a motor adaptation task (walking with a robotic orthosis) demonstrated that although motor practice was conducted in the absence of cutaneous pain, when skill-learning tests were performed in the presence of tonic cutaneous pain (experimentally induced), the presence of pain during the test phase did not interfere with overall performance relative to the practice phase. That is, motor performance was comparable to that observed during practice. This finding contradicts the principle of Specificity of practice, as a decline in Performance would have been expected following a change in testing conditions (i.e., the induction of pain) (13).

Considering the divergent findings of previous studies, the existing research gap in this area, and the presence of both supporting and contradictory evidence regarding the principle of Specificity of practice, it is necessary to conduct further investigations that rigorously examine this principle. Although numerous studies have addressed the Specificity of practice, existing inconsistencies concerning the validity and accuracy of this principle highlight the need for additional research. Moreover, most studies on the principle of Specificity of practice have been conducted in laboratory settings or have employed a limited number of variables associated with this principle. Consequently, fewer studies have examined practice specificity in active environments that include feedback and consider environmental (contextual) components. Therefore, the present study seeks to address these limitations by examining the effects of the Specificity of practice principle on the Performance and learning of a perceptual–motor dart-throwing skill. Specifically, the present research aimed to answer the following question: Does the principle of Specificity of practice influence the Performance and Retention of the dart-throwing skill? Is the Performance of dart throwing, as a real-world skill, dependent on the practice conditions, either general conditions (inactive practice environment without feedback, presence of spectators, and rewards) or specific conditions (active practice environment with feedback, presence of spectators, and rewards)? To address these questions, novice participants, following a training period (acquisition phase), were tested in both a post-test and a retention test. In each test, participants were assessed once under practice conditions identical to those of the acquisition phase and once under different practice conditions. If participants' Performance declined as a result of changes in testing conditions, this would be interpreted as support for the principle of Specificity of practice. The findings of this study may provide practical implications for movement educators, rehabilitation therapists, and coaches in the domain of motor skill training and practice design. Specifically, the results may contribute to a clearer understanding of the most effective environments for the Performance and learning of motor tasks, thereby facilitating the application of these findings in practical settings.

Materials and Methods

The present study employed a quasi-experimental design and was applied in nature with respect to its objective. The research was conducted in a field setting. A pre-test–post-test design was used across two practice conditions (general and specific), with a practice period and a retention test for each group.

The statistical population of this study consisted of all students aged 12 to 15 years in District 8 of Tehran. Based on a previous study (3) and using G*Power (version 3.1.5, Freeware, University of Düsseldorf, Düsseldorf, Germany), with a significance level of $\alpha = 0.05$ and a statistical power of $\beta = 0.80$, a sample size of 30 participants was estimated. Participants were selected through purposeful and convenience sampling and met the inclusion criteria of right-handedness, neurological health, and no prior familiarity or experience with the experimental task. The selected participants were randomly assigned to two groups of 15 individuals each: a specific-practice condition group and a general-practice condition group. All participants were novices in the target task, aged 12–15, provided informed consent, and were in good overall health.

To evaluate the participants, a demographic information questionnaire was first administered. Subsequently, the Persian version of the General Health Questionnaire (GHQ) was used to assess general health status and the absence of physical disorders; this questionnaire has a reported reliability coefficient of 0.91. In addition, to obtain supplementary information related to students' health, their educational records were reviewed, and relevant information was collected from their coaches and parents. Based on this information, participants' general health status was confirmed, and children with specific medical conditions were excluded from the statistical sample (14). Furthermore, for the assessment of dart-throwing Performance as well as for the practice and testing phases, a standard dartboard and darts were used. The dartboard was circular, made of compressed paper, with a diameter of 453 mm and a thickness of 12 mm. The throwing distance from the starting line to the dartboard for children was 2.37 m, and the height of the dartboard center from the ground was 1.22 m, respectively (Figure 1). Proper considerations regarding stance and dart grip were observed throughout the task. Each participant was provided with three darts for the throws; all darts were identical in terms of material, design, and weight. During the study, the score for each throw was recorded on a scale of 1 to 10 (equivalent to 10 to 100 points). Participants' throwing scores were recorded from 0 (missed the dartboard) to 10 (dart center).

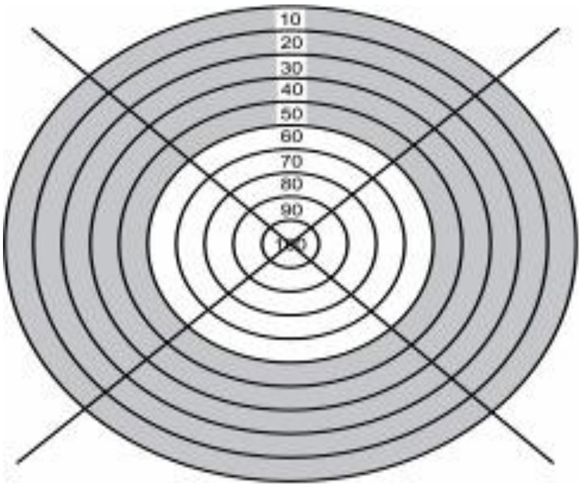

Figure 1. Schematic view of the dart-throwing target

Data Collection Procedure: Data collection was conducted as follows. First, the necessary permissions for cooperation with the students were obtained. Subsequently, appropriate announcements were made to recruit participants, and volunteer application forms and informed consent forms were completed and reviewed by interested students. After all inclusion criteria were fully verified, eligible participants were enrolled in the study and participated in the research procedures described below.

Preliminary Instruction Phase: During this phase, participants received an explanation of the study's purpose, the importance of the dart-throwing task, and verbal instructions for dart throwing. These instructions included the proper grip on the dart, the correct body position in front of the dartboard, and the appropriate technique for executing the throw. Following this, the examiner demonstrated the criterion skill in a slow, controlled manner, accompanied by verbal explanations. Subsequently, to ensure task familiarity, each participant was allowed to practice the task by correctly gripping the dart, assuming the proper throwing position, and performing several practice throws.

Practice Procedure in the Specific Practice Conditions Group: In the specific practice conditions group, following participation in the preliminary instruction phase, specific practice conditions were created based on the approach proposed by Schmidt et al. (1). To establish a task-specific and motivational environment, spectators including active dart athletes, dart coaches, and members of the executive staff were invited to be present at the practice venue. In addition, a competitive selection setting was implemented to identify the best performers, thereby enhancing motivational demands during practice. Furthermore, rewards were given to participants who ranked first through third in Performance. To provide augmented feedback, two dart coaches were asked to offer participants corrective feedback on technical errors and instructional strategies to improve dart-throwing effectiveness (1, 3).

Practice Procedure in the General Practice Conditions Group: The conditions for this group were identical to those of the specific practice group, except that spectators, active dart practitioners, and coaches were not present. Additionally, no rewards were offered to top performers, and no feedback was provided during the practice sessions.

Pre-test: Following the preliminary instruction phase, a pre-test was administered to ensure homogeneity among participants. During this stage, participants performed one block of 10 trials of the criterion task (dart throwing). The score for each throw was calculated and recorded according to the scoring system. Based on their pre-test performance, participants were assigned to either the Specific Practice Conditions group (n = 15) or the General Practice Conditions group (n = 15) to ensure that both groups were matched on initial skill level.

Criterion Task Practice: During this phase, participants in both the Specific Practice Conditions Group and the General Practice Conditions Group performed the criterion dart-throwing task according to their respective practice conditions. Each participant completed six training sessions and, in each session, executed three blocks of 10 trials of the criterion task, consistent with the designated conditions for their group.

Post-test: Immediately after the final practice session, all participants completed the post-test. In this stage, similar to the pre-test, each group performed one block of 10 trials of the criterion dart-throwing task.

Participants in the General Practice Conditions Group completed the test once under their normal (practice-like) conditions and once under the specific conditions (different from their practice setting). Conversely, participants in the Specific Practice Conditions Group performed the post-test once under their specific (practice-like) conditions and once under the general conditions (different from practice). The resulting data were recorded as post-test performance scores.

Retention Test: Twenty-four hours after the post-test, participants performed an additional 10-trial block to assess Retention of motor learning. Similar to the post-test, both groups completed the task once under the same conditions as their practice phase and once under the alternate condition. The performance results obtained were recorded for subsequent analysis.

After data collection, statistical analysis was performed using SPSS software (version 23, IBM Corporation, Armonk, NY). Descriptive statistics were used to calculate the mean and standard deviation and to generate the relevant charts. The Shapiro–Wilk test was used to assess the normality of the data distribution. To compare Performance between groups, the Independent Samples t-test was used, and to test the Specificity of Practice Hypothesis, the Paired Samples t-test was applied. For this purpose, the mean score of the criterion task in each group during the pre-test phase was compared with the mean score of the same criterion skill obtained in the retention phase for that group. The significance level (alpha) for all statistical analyses was set at $P < 0.05$.

Results

Table 1 presents the demographic characteristics of the participants, including age, height, weight, and body mass index (BMI), for the two experimental groups separately. According to the significance column in this table, the Independent Samples t-test results indicated no significant differences between the two groups in their individual characteristics, confirming that the groups were homogeneous.

Based on Table 2, the results of the paired-samples t-test indicated significant changes in the specific practice group from pre-test to post-test under both practice-matched and practice-dimmatched conditions ($p < 0.05$). This indicates that participants in this group achieved significantly higher post-test scores under both conditions than at the pre-test. Furthermore, the results of the paired-samples t-test showed significant changes in the normal practice group from pre-test to post-test under both practice-similar and practice-dissimilar conditions ($p = 0.001$). In other words, this group likewise obtained significantly higher post-test scores in both conditions compared with their pre-test scores.

According to table 3, a significant difference was observed between the post-test and retention-test performances of the specific practice group under practice-matched and practice-mismatched conditions. Comparison of the mean scores showed that participants in the specific practice group performed significantly better on both the post-test and the retention test under practice-matched conditions than under practice-mismatched conditions. Similarly, in the normal practice group, participants demonstrated significantly higher Performance in both the post-test and retention test under practice-matched conditions compared to practice-mismatched conditions. These findings provide support for the Specificity of Practice Hypothesis. In other words, participants in both groups exhibited a decline in Performance when tested under conditions that did not match those experienced during practice, confirming that motor skill performance and learning are optimized when testing conditions closely match practice conditions (Figure 2).

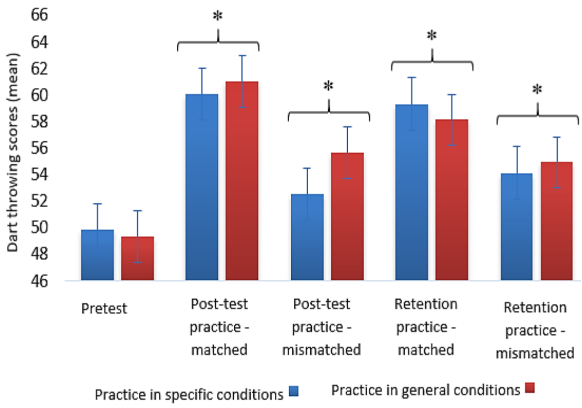

Figure 2. Dart throwing Performance across study phases

Table 1. Mean and standard deviation of participants' demographic characteristics

Variable	Group		P value
	Practice in the specific condition (mean ± SD)	Practice in the general condition (mean ± SD)	
Age (years)	13.00 ± 0.98	13.00 ± 0.83	0.43
Height (cm)	147.40 ± 1.87	145.30 ± 3.93	0.21
Weight (kg)	37.20 ± 3.83	35.30 ± 0.97	0.26
BMI (kg/m^2)	19.30 ± 0.12	19.10 ± 0.18	0.52

SD: Standard deviation

Table 2. Results of the paired t-test for changes from pre-test to post-test under practice similar and practice dissimilar conditions in the specific and normal practice groups

Group		Pre-test (mean ± SD)	Post-test (mean ± SD)	df	t value	P value
Specific Practice	Practice-matched	49.8 ± 8.78	60.06 ± 8.81	14	−9.304	0.001
	Practice-mismatched	49.5 ± 1.71	52.5 ± 7.52	14	−2.280	0.039
Normal Practice	Practice-matched	48.6 ± 6.67	61.06 ± 6.71	14	−18.804	0.001
	Practice-mismatched	48.5 ± 6.61	55.6 ± 5.77	14	−10.990	0.001

SD: Standard deviation; df: Degree of freedom

Table 3. Results of the paired t-test comparing post-test and retention test performance under practice- matched and practice- mismatched conditions in the specific and normal practice groups

Group	Post-test matched
Specific Practice	
Normal Practice	
Specific Practice	
Normal Practice	

SD: Standard deviation; df: Degree of freedom

In contrast, the comparison between the Arch Test and the declined trunk extension had a trivial effect size and was not significant. For the Iliocostalis muscle, the differences between the Arch Test and the prone trunk extension, and between the Arch Test and the declined trunk extension, had huge effect sizes and were significant. However, the comparison between prone and declined trunk extensions showed a trivial effect size and was not significant, indicating a similar muscle response between the two tasks. For the Multifidus, the prone trunk extension produced the largest effect size, although its difference compared to the Arch Test was not statistically significant. The comparison between the declined trunk extension and the Arch Test showed a significant medium effect. Therefore, for targeted Multifidus training, prone trunk extension likely induces greater activation, but it should be noted that differences from other tasks are not always detectable. Overall, these results show that prone trunk extension is generally associated with greater trunk muscle activation, but the muscle response pattern varies across muscles. Notably, for the Iliocostalis, prone and declined trunk extension produce relatively similar responses. A negative sign for the effect size indicates that the direction of the difference was such that the muscle activity was greater in the second movement compared to the first.

Discussion

The Maximal Voluntary Contraction is the most widely applied method for normalizing EMG data (3). However, there are concerns about the validity of MVC for normalizing EMG data from posterior lumbar muscles, especially when lumbar spinal loading needs to be investigated in future studies. This is because using MVC is essential for accurately assessing muscle activity and validating the models used in such research (8, 9). The present study, aimed at determining the effect of manual resistance against different tasks in the MVC test, showed that the prone trunk extension is likely more suitable for assessing the MVC of the Longissimus and Multifidus muscles. In contrast, both the prone and declined trunk extension tasks appear suitable for the MVC of the Iliocostalis muscle. The Arch Test was the least preferred task for all three muscles.

Similar studies vary significantly in their execution procedures and participant conditions, and there is no consensus on the MVC task (4, 9, 11, 12, 19, 24). Furthermore, few studies have investigated electromyography during lumbar spinal loading in active young individuals (12). Typically, in lumbar spinal loading studies, the activity of the posterior lumbar muscle group is reported during the declined trunk extension (8, 9, 19). However, MVC studies on posterior spinal muscles have suggested the prone trunk extension and the Arch Test (12, 13, 16, 24). Due to methodological differences among existing studies, it is challenging to compare results and propose a standard method. This study on active young men showed that manual resistance during prone trunk extension was a suitable method for reporting MVC in the Longissimus, Iliocostalis, and Multifidus muscles of the lumbar region, although, for the Iliocostalis, the decline trunk extension showed no significant difference from the prone trunk extension.

The differences in results from these participants compared with past research are likely related to differences in muscle recruitment strategies among active individuals (24). Additionally, an increase in muscle cross-sectional area can lead to fiber pennation, changes in muscle length, changes in muscle lever arms, and changes in muscle orientation. A distinguishing feature of this study compared to similar ones was the inclusion of subcutaneous fat as a control criterion and the low body fat percentage among the active young participants, which improved sEMG data quality. This contrasts with past studies that primarily focused on healthy (11, 12, 14, 24) or patient (4, 9) populations, did not provide information on participants' fitness levels, and limited anthropometric conditions to height and weight.

In the present study, all three lumbar muscles were specifically examined independently, whereas previous research has focused on the aggregate activity level of the erector spinae (11, 12, 16). Participants in this research were homogeneous in terms of fitness level for the strength factor and anthropometrics. Their sEMG data demonstrated consistent quality and similar levels of muscle activity across all tasks, a characteristic less commonly observed in the literature (4, 11, 14, 16). In the present study, men were selected for their availability, lower body fat percentage, and high muscular strength, whereas prior studies predominantly examined women (12, 14). These findings can effectively contribute to validating biomechanical models and to designing targeted training programs for physically active individuals. Given the mean values and the small range of variation, which ensures data stability, the prone trunk extension task is proposed as the recommended method for achieving MVC in active participants.

Limitations

Stronger muscles produce clearer signals, and a lower body fat percentage reduces noise and cross-talk. For these reasons, the age range and fitness level were controlled in the present study. Due to laboratory limitations, female participants were not included. Therefore, the most significant limitations of this research were the number of participants, their gender, age range, and fitness level, which prevent generalizing the results to active women and active individuals in other age groups. Furthermore, this study examined only three tasks involving three lumbar spine muscles, and no conclusions can be drawn about other tests or muscles based on the existing results.

Recommendations

It is recommended that future studies replicate this process across both women and men, across different age groups and fitness levels, and consider muscles in both the thoracic and lumbar regions. Additionally, applying both manual and non-manual resistance in other tests should be considered.

Conclusion

Based on the results of this study, the prone trunk extension produced the most significant activation in the lumbar muscles. Given the control of body fat percentage and fitness level of the participants, the prone trunk extension is proposed as a viable method for determining MVC in active men. It can help validate biomechanical models and design targeted training programs. Selecting appropriate tasks for the target population is essential for obtaining valid and reliable data.

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Authors' Contribution

Project Design and Conceptualization: Amir Sadeghi-Golafzani, Raghad Mimar
Attracting Financial Resources to carry out the Project: Amir Sadeghi-Golafzani, Raghad Mimar
Project Support Scientific and Executive Services: Amir Sadeghi-Golafzani, Raghad Mimar
Providing Equipment and Statistical Sample: Amir Sadeghi Golafzani
Data Collection: Amir Sadeghi-Golafzani
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Conflict of Interest

The authors did not have a conflict of interest.

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